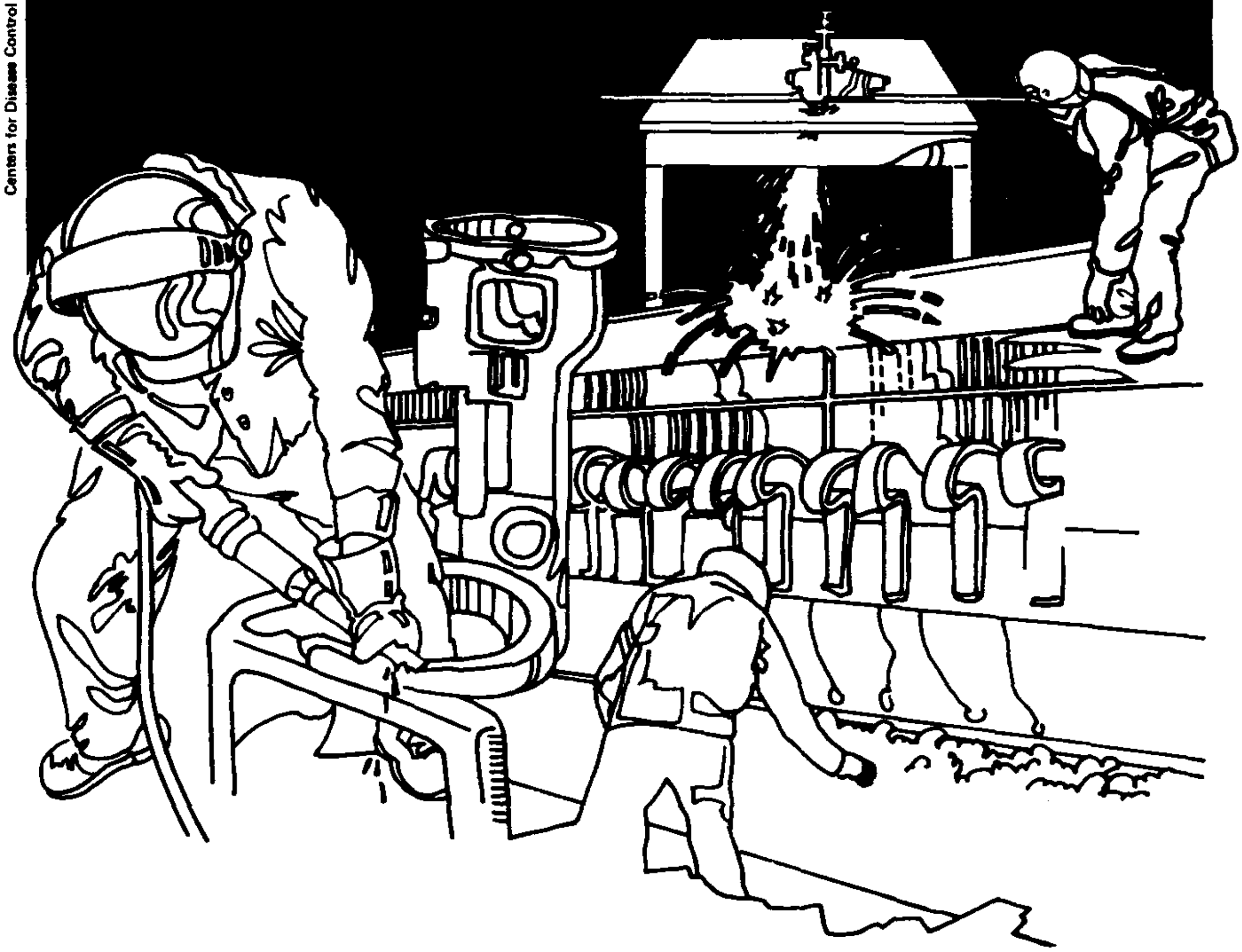
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
Centers for Disease Control ■ National Institute for Occupational Safety and Health

NIOSH



Health Hazard Evaluation Report

HETA 89-136-1991
BLUE RANGE MINING COMPANY
LEWISTOWN, MONTANA

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

HETA 89-136-1991
OCTOBER 1989
BLUE RANGE MINING COMPANY
LEWISTOWN, MONTANA

NIOSH INVESTIGATORS:
William J. Daniels, CIH
Thomas R. Hales, M.D.

I. SUMMARY

On February 13, 1989, the National Institute for Occupational Safety and Health (NIOSH) received a request to evaluate employee exposures to lead at Blue Range Mining Company, Lewistown, Montana. The company utilizes lead oxide to extract precious metals from mining samples in a process known as "fire assaying."

In March 1989, NIOSH investigators conducted an environmental and medical survey at the facility. Personal breathing zone (PBZ) and area air samples were collected in the fire assay laboratory to determine concentrations of airborne lead and other trace metals. Air velocity measurements of the local exhaust ventilation systems also were made. Selected employees completed a self-administered questionnaire, a medical and occupational history, a limited physical examination, and a blood analysis for blood lead and free erythrocyte protoporphyrin (FEP).

An 8-hour time-weighted average (TWA) concentration of 850 micrograms lead per cubic meter of air (ug/M^3) was found in the PBZ sample for the assayist. This concentration is above the Mine Safety and Health Administration (MSHA) standard of 150 ug/M^3 as an 8-hour TWA, and the Occupational Safety and Health Administrations (OSHA) Permissible Exposure Limit (PEL) of 50 ug/M^3 as an 8-hour TWA. The employee was wearing respiratory protection, and therefore, the actual exposure should have been substantially less than this value, provided that the respirator was properly fitted and maintained. This employee's blood lead level was 50 ug/dl and FEP was 51 ug/dl at the time of this investigation. The results of short-term PBZ samples indicated that mixing and dispensing the flux probably contributed the most to the exposure. The results of area air samples analyzed for trace metals revealed that no other metals were present in significant amounts at the time of the survey when compared to their environmental criteria.

The assay lab employees reported an increased frequency and intensity of symptoms consistent with lead poisoning compared to non-assay lab employees; however, none of these frequencies were statistically significant. The mean blood lead levels were significantly higher among the assay lab employees compared to the non-assay lab employees. One of the four (25%) of the assay lab workers had a blood lead level of 50 ug/dl (the OSHA standard requires removal from the area where the lead exceeds the action level (30 ug/M^3).[16] The mean FEP levels were significantly higher among the assay lab employees compared to the non-assay lab employees. Two of the four assay lab workers (50%) had FEP levels at or above 50 ug/dl (normal range <50 ug/dl).[16]

On the basis of the data collected during the survey, the investigators concluded that a health hazard existed from employee exposure to lead in the fire assay operations at Blue Range Mining Company. Recommendations designed to reduce exposures are included in this report.

KEY WORDS: SIC 1041 (Gold Ores), Fire Assay, Gold Assay, Lead, Blood Lead, FEP, Litharge, Ventilation

II. INTRODUCTION

On February 13, 1989, NIOSH received a request from Blue Range Mining Company, Lewistown, Montana, to evaluate employee exposures to lead in the company's fire assay operations.

On March 13, 1989, NIOSH personnel conducted an environmental and medical survey of the facility. The environmental survey was composed of: 1) obtaining background information on operations in the fire assay laboratory, 2) taking air flow measurements of the local exhaust ventilation system, and 3) collecting personal breathing zone and area air samples for lead and trace metals. The medical component of this study was composed of: 1) a self-administered questionnaire, 2) a medical and occupational history, 3) a limited physical examination, and 4) a blood analysis for blood lead and free erythrocyte protoporphyrin (FEP). The environmental results were provided to company representatives by letter on April 21, 1989. The blood lead and FEP results were reported to participating employees by telephone and mail on April 3, 1989.

III. BACKGROUND

A. General Description of Fire Assaying

The fire assaying process separates noble metals, such as gold and silver, from their ores using dry reagents and heat. The process can be traced back to 2600 B.C., however fire assaying is still used today due to its ability to concentrate minute amounts of precious metals from relatively large ore samples.[1] Despite its long history, the exact chemical reactions involved in the process are not completely understood.

The first step in the fire assay process is "sample preparation." During this step the various ore samples are ground, milled, and crushed to approximately 5 mesh size. The second step is "charge" preparation. "Charges" are prepared in a fireclay crucible by adding dry reagents (flux) to a finely crushed sample of the ore. The dominant reagents used in this operation are lead oxide and wheat flour. Other flux reagents include sodium carbonate, silica, borax, and potassium nitrate in varying concentrations.[1] To extract all the precious metals from each ore sample, the flux's composition needs to be "adjusted" to accommodate the ore's oxidizing, reducing, or neutral characteristics. This delicate process of "adjusting" the flux to accommodate the ore's characteristics makes assaying as much an art as a science.

The third step is called crucible fusion. In this process approximately 24 of the "charged" fire clay crucibles are placed in a furnace. As the temperature reaches approximately 1600°F, the carbon contained in the flour reduces a portion of the lead oxide to lead droplets. These droplets then alloy with the noble metals released from the decomposed ore. The remaining litharge forms silicates and other compounds which mix with the slag produced from the ore. After

44 to 55 minutes, the crucibles are removed from the oven and the molten contents are quickly poured into iron molds. The lead droplets then settle through the slag to form a "button" at the bottom of each mold. After cooling, the slag is broken away from the molds using a small hammer, and the lead buttons containing the noble metals are collected.[1]

The third stage involves separating the noble metals from the lead in a process called "cupellation." The lead buttons obtained from the crucible fusion are hammered into squares and placed in small containers made from compressed bone ash (cupels). The cupels are reintroduced into the furnace at approximately 1500°F for 60-75 minutes. The lead button oxidizes into molten lead oxide, of which 98.5% is absorbed into the porous cupel, and 1.5% is volatilized.[1] The bone ash cupel absorbs the molten lead oxide, but is impermeable to the noble metals. Thus, when the cupels are removed from the oven, small beads of the noble metals remain in the center of each cupel. These beads are then weighed and further analyzed for their gold and silver content.[1]

B. Description of Company Operations

Blue Range Mining Company, located in Lewistown, Montana, is engaged in underground mining for gold and silver. To determine the precious metal content of various ore samples, the fire assay laboratory is utilized. The fire assay laboratory located at the refining site has been operating since 1989. The lab processes an average of 80 ore samples per week, using approximately 100 pounds of litharge.

Four employees work in the laboratory, two as assayists, and two as sample preparation employees. These employees generally work 5 eight-hour work shifts per week with occasional overtime, with the assayists working during the day shift, and the sample preparation employees working during the evening shift. The two assayists alternate responsibilities; one employee prepares the charges and operates the furnaces, while the other weighs the precious metal and records the data.

The laboratory consists of five interconnected rooms. The furnace room contains one crucible fusion furnace and one cupel furnace, two work tables to prepare the crucible charges, and two work tables for pouring the crucibles into the molds. Adjacent to the furnace room is the sample-preparation room where ore samples are milled and crushed. The other 3 rooms are all connected to the sample-preparation room: the scale room where the noble metal beads are weighed, the maintenance shop where the flux is mixed, and a break room.

C. Personal Protection, Administrative and Engineering Controls

Personal protective equipment worn by the employees when in the assay laboratory included coveralls, gloves, face shields, and respirators. One assayist utilized a half-face piece respirator with high efficiency particulate filters (NIOSH Certification Number

TC-21C-244), while the other assayist, who only worked briefly in the assay lab working during the period of the survey, reportedly used a disposable dust mask (TC-21C-361). Respirators were worn in the furnace rooms while performing the following procedures: preparing charges, removing the crucibles from the furnace, and removing the cupels from the furnace. The respirators were also worn in the maintenance shop during flux mixing. The employees wear their coveralls at all times when in the assay laboratory. The employees are responsible for laundering their own coveralls, which they reportedly do approximately once per week. Smoking and eating are only allowed inside of the break room. Hand washing facilities are located in the assay lab; however, no shower or change room was present at the laboratory.

The engineering controls present in the furnace room consisted of four different local exhaust ventilation systems. A slotted local exhaust hood was present in the area where the crushed ore samples are added to the crucibles. The crucible and cuppelation furnaces are both equipped with a slot exhaust hood located directly above the furnace door, and a second hood located on the back of the furnace. A canopy hood is also located directly above the table where the crucibles are placed after being removed from the fusion oven. All of the hoods are ducted directly to the outside of the building. Make-up air is drawn into the room through ducts located directly below each of the ovens, and through a hole located in the ceiling plenum of the room. No fans were used on the make-up air system.

Medical monitoring of employees included pre-employment blood lead levels which were to be repeated every six months. No environmental surveys had been conducted at the facility during its first three months of operation.

IV. MATERIALS AND METHODS

A. Environmental

On March 13, 1989, an environmental survey was conducted to determine employee exposures to lead and trace metals. During this survey, personal breathing zone (PBZ) air samples were collected near the workers' breathing zone, and general area air samples were collected at locations throughout the assay laboratory. Samples were obtained using battery-powered sampling pumps operating at 1.8 and 4.0 liters of air per minute. The pumps were attached by Tygon tubing to the collection medium (37-millimeter, 0.8 micron pore size, mixed-cellulose ester membrane filters contained in 3-piece plastic cassettes).

The samples were analyzed for lead by atomic absorption spectroscopy according to NIOSH method 7082.[2] In addition, two of the samples were analyzed for 30 trace metals using inductively coupled plasma - atomic emission spectroscopy in accordance with NIOSH Method 7300.[2]

Air flow measurements of the local exhaust ventilation hoods were taken with a Kurz Model 490 mini-anemometer.

B. Medical

The four assay lab employees (the two assayists and the two sample preparation employees) and three randomly selected non-assay lab employees working in the company's adjacent building were invited to participate in the study. To allow statistical analysis, the questionnaire data from this plant was combined with the data from this company's other assay lab located in Butte, Montana (HETA 89-213). The assay process, the study design, and the data collection for the Butte assay lab was performed in the same manner. The two assay lab employees working in the Butte laboratory (one assayist and one sample preparation employee) and two randomly selected non-assay lab employees working in the adjacent room were invited to participate in the study. The study consisted of: 1) a medical and occupational history, 2) a limited physical examination, 3) a blood sample analyzed for lead and free erythrocyte protoporphyrin (FEP), and 4) a self-administered questionnaire. The questionnaire was designed to gather demographic information and symptoms associated with lead poisoning. Each of the 20 symptom questions was scored on a 4-point scale: "not at all" (score = 1), "a little" (score = 2), "moderately" (score = 3), and "quite a lot" (score = 4). Four symptoms were combined into one of five symptom clusters: constitutional, cognitive, gastrointestinal (GI), emotional, and peripheral nervous system (PNS) (Table 2). Cluster scores could range from 4 to 16, reflecting the frequency and intensity of the individual's symptoms within that cluster. Mean symptom cluster scores were calculated for the assay lab employees and the non-assay lab employees. We defined a case of symptomatic lead poisoning as any symptom cluster with a score of 8 or more, and report the number of cases between the assay lab employees and the non-assay lab employees.

Statistical analyses were performed using EPIINFO and SPSS/PC.[3,4] The mean symptom cluster scores were analyzed using parametric (student's t-test) and non-parametric (Kruskal-Wallis) statistical procedures. Only the parametric results are reported unless there was discrepancy between the two tests rendering an association "statistically significant" in which cases we report both results. Statistical significance was defined as p less than 0.05.

The blood leads and FEPs were analyzed in one of the OSHA-CDC (Occupational Safety and Health Administration-Centers for Disease Control) approved laboratories for blood lead analysis based on proficiency testing.[5] The blood leads were determined utilizing anodic stripping voltimetry, and FEPs were determined by photofluormetric techniques.[6]

The medical and occupational history, and limited physical examination was performed by a NIOSH physician trained in internal and occupational medicine. The limited physical examination consisted of an inspection of the employee's gums for signs of lead exposure (Burtonian lead line).[7]

V. EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects. It is important, however, to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a preexisting medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects often are not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes and, thus, potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent becomes available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), 3) the U.S. Department of Labor/Occupational Safety and Health Administration (OSHA) occupational health standards [Permissible Exposure Limits (PELs)], and 4) the Mine Safety and Health Administration (MSHA) standards. Often, the NIOSH recommendations and ACGIH TLVs are lower than the corresponding OSHA or MSHA standards. Both NIOSH recommendations and ACGIH TLVs usually are based on more recent information than are the OSHA and MSHA standards. Also, in some cases, the OSHA standards may be more restrictive than the corresponding MSHA standards. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that the company is required by the Mine Safety and Health Administration to meet those levels specified in an MSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday.

A brief discussion of the toxicity and evaluation criteria for inorganic lead follows. A summary of the lowest observable effect levels in adults are listed in Table 3.

A. Toxicological

Inhalation (breathing) of lead dust and fume is the major route of lead exposure in the industrial setting. A secondary source of exposure may be from ingestion (swallowing) of lead dust deposited on food, cigarettes, or other objects. Once absorbed, lead is excreted from the body very slowly. Absorbed lead can damage the kidneys, peripheral and central nervous systems, and blood forming organs (bone marrow). These effects may be felt as weakness, tiredness, irritability, digestive disturbances, high blood pressure, kidney damage, mental deficiency, or slowed reaction times. Chronic lead exposure is associated with infertility and with fetal damage in pregnant women. There is some evidence that lead can also impair fertility in occupationally exposed men.[8]

The blood lead test is one measure of the amount of lead in the body and is the best available measure of recent lead absorption. Adults not exposed to lead at work usually have a blood lead concentration less than 30 ug/dl; the average is less than 15 ug/dl.[9,10] In 1985, the Centers for Disease Control (CDC) recommended 25 ug/dl as the highest acceptable blood level for young children.[11] Since the blood lead concentration of a fetus is similar to that of its mother, and since the fetus's brain is presumed to be at least as sensitive to the effect of lead as a child's, the CDC advised that a pregnant woman's blood lead level be below 25 ug/dl.[11] Recent evidence suggests that the fetus may be adversely affected at blood lead concentrations well below 25 ug/dl.[12] Furthermore, there is evidence to suggest that levels as low as 10.4 ug/dl affect the performance of children on educational attainment tests, and that there is a dose-response relationship with no evidence of threshold or safe level.[13] Lead levels between 40-60 ug/dl in lead-exposed workers indicate excessive absorption of lead and may result in some adverse health effects. Levels of 60-100 ug/dl represent unacceptable elevations which may cause serious adverse health effects. Levels over 100 ug/dl are dangerous and require medical treatment.

Free erythrocyte protoporphyrin (FEP) levels measure the effect of lead on heme synthetase, the last enzyme in heme synthesis. FEP levels increase abruptly when blood lead levels reach about 40 ug/dl, and they tend to stay elevated for several months. A normal FEP level is less than 50 ug/dl.[14]

B. Occupational Exposure Criteria

The current MSHA standard for inorganic lead is 150 micrograms per cubic meter of air (ug/M^3) as an 8-hour TWA.[15] It should be noted that this standard is based on the 1973 ACGIH TLV for inorganic lead. The current OSHA PEL for airborne lead is 50 ug/m^3 calculated as an 8-hour TWA for daily exposure.[16] In addition, the OSHA lead standard establishes an "action level" of 30 ug/m^3 TWA which initiates several requirements of the standard, including periodic exposure monitoring, medical surveillance, and training and education. For example, if an employer's initial determination shows that any employee may be exposed to over 30 ug/m^3, air monitoring must be performed every six months until the results show two consecutive levels of less than 30 ug/m^3 (measured at least seven days apart). The standard also dictates that workers with blood lead levels greater than 50 ug/dl must be removed from further lead exposure. The affected employee must be removed from further lead exposure until the blood lead concentration is at or below 40 ug/dl. Removed workers have protection for wage, benefits, and seniority for up to 18 months until their blood levels decline to below 40 ug/dl and they can return to lead exposure areas.[16]

VI. RESULTS AND DISCUSSION

A. Environmental

1. Air Samples

The results of the environmental survey are contained in Table 1. As evidenced by these data, an 8-hour TWA concentration of 850 ug/M^3 was found in the PBZ sample collected for the assayist. This concentration is above the MSHA standard for inorganic lead of 150 ug/M^3 as an 8-hour TWA, and the OSHA PEL of 50 ug/M^3 as an 8-hour TWA. It should be noted that the employee was wearing respiratory protection when performing the operations where the lead exposure would have been greatest. Provided that the respirator was properly fitted and maintained, the actual exposure would be expected to be substantially lower than the measured value.

Table 1 also contains the results of short-term PBZ samples which were collected to define exposures which occurred during specific tasks in the fire assay process. A task which contributed substantially to the overall exposure was the mixing of the flux. During this procedure, a concentration of 13,000 ug/M^3 was measured during the 38 minute process. This task, which reportedly occurs only once per week, is carried out using a "cement" type mixer without the use of local exhaust ventilation. Another task which contributed substantially to the assayist's exposure was the dispensing of flux into the crucibles. When this operation was monitored at the location where it was routinely conducted, a concentration of 130,000 ug/M^3 was found during the one and one half minute procedure. The next time that this task was carried out, it was relocated next to the crucible cooling hood. The concentration was found to decrease to 36,000 ug/M^3 during the two minute sample. It should be noted that these sample concentrations are calculated for short-term durations of exposure, and as such, should not be compared to evaluation criterion based on 8-hour TWAs.

Also present in Table 1 are the results of general area air samples collected in the furnace room, as well as the other rooms comprising the assay laboratory. As evidenced by these data, the highest TWA concentrations of lead was found in the furnace room (74, 110, and 110 ug/M^3), followed by the sample preparation and scale rooms (30 ug/M^3 each), with no lead detected in the sample collected in the break room.

Two general area air samples collected in the furnace room were also analyzed for trace metal content. The results of the analysis revealed the primary metallic component to be lead. In addition, trace quantities of calcium, iron, magnesium, and tin were found. However, the concentrations of these contaminants were far below their respective evaluation criteria.

2. Ventilation Measurements

Air velocity measurements taken below the hood at the center of the crucible and cupel furnace doors revealed a flow rate of 150 feet per minute (fpm) in the direction of the local exhaust hood. Measurements taken at table level under the crucible cooling hood revealed flow rates of 150 fpm at the center of the table, and 300 fpm at the front and each of the sides of the table. Measurements taken at the slot hood where the ore was prepared revealed a velocity ranging from 150 to 200 fpm at a working distance of one foot from the hood. While there are no standards or regulations for air flow which govern these operations, the ACGIH recommends that capture velocities for substances released at low velocity into moderately still air be at least 100 to 200 fpm, and that the upper end of this range be used for contaminants of high toxicity (e.g., lead).[17]

B. Medical

All seven selected employees of the Lewistown lab and four selected employees of the Butte lab participated in the study. These 11 employees were composed of 6 assay lab employees, and 5 non-assay lab employees. No statistically significant differences were found for age, sex, and race between assay and non-assay lab employees (Table 4).

The assay lab employees reported an increased mean score of constitutional, cognitive, emotional, and peripheral nervous system symptom complexes compared to the non-assay lab employees; however none of these were statistically significant (Table 5).

Two of the six (33%) assay lab employees (one assayist and one sample preparation employee) satisfied our case definition for symptomatic lead poisoning (any symptom cluster score of 8 or more). The Lewistown assayist had a constitutional symptom cluster score of 8 and a blood lead level of 50 ug/dl, while the Butte sample preparation employee had a cognitive symptom cluster score of 12 and a blood lead level of 65 ug/dl. None of the non-assay lab employees met our case definition and none had a blood lead level over 36 ug/dl.

The mean blood lead levels were significantly higher among the assay lab employees compared to the non-assay lab employees (Table 6). Three of the six (50%) of the assay lab workers were above 40 ug/dl (the OSHA standard for monitoring the blood lead every 2 months) and two of the six (33%) of the assay lab workers were above 50 ug/dl (the OSHA standard for removal from the area where the lead exceeds the action level (30 ug/M^3).[11] None of the five non-assay lab employees were above 36 ug/dl.

The mean FEP levels were significantly higher among the assay lab employees compared to the non-assay lab employees (Table 6). Three of the six assay lab workers (50%) were above the normal range (<50 ug/dl), while none of the five non-assay lab employees were above the normal range.

None of the 11 employees had signs of lead exposure on their gums (Burtonian lead line).

D. Personal Protection, and General Housekeeping

Observations made during the course of the environmental survey revealed some instances of improper use and storage of personal protective equipment. This included the failure of the assayist to wear coveralls at the start of the assaying duties. Such practices could allow the employees' work clothing to become contaminated with lead which could be spread to other areas of the facility or the home. Respirators were also noted to be temporarily stored on a table in close proximity to where the powdered flux was dispensed. Since contamination of the inner surface of the respirator can occur under such circumstances, care should be taken to store respirators in an area free from lead exposure when not in use. Dry sweeping was also used to clean the flux mixing area and the furnace room at the end of the shift. Since this method of cleaning can actually lead to the dispersion of additional lead dust, other techniques such as vacuuming should be used for cleaning.

VII. CONCLUSIONS

The environmental survey revealed lead exposures above the MSHA and OSHA PELs for the assayist. A substantial part of the exposure occurred during the flux mixing and dispensing operations which did not have local exhaust ventilation. At the time of the survey, recommendations were made to add ventilation to these operations. In follow-up conversations with the company, it was reported that these recommendations had been followed and the new ventilation systems were operable. Therefore, if properly constructed, the new local exhaust ventilation systems should reduce the potential employee exposures to levels substantially below those measured during this survey. However, documentation of the reduction of these levels should be verified by additional environmental sampling.

The medical study revealed one Lewistown assayist having constitutional symptoms consistent with lead poisoning and a blood lead level of 50 ug/dl, and one Butte sample preparation employee having cognitive symptoms consistent with lead poisoning and a blood lead level of 65 ug/dl.

VIII. RECOMMENDATIONS

To ensure that workers are adequately protected from the adverse effects of lead, a comprehensive program of surveillance and prevention is needed. The guidelines for such a program are clearly presented in the OSHA lead standard.[16] Although compliance with the OSHA standard is not required for facilities covered by MSHA, it is considered to be the more appropriate evaluation criterion for the purposes of this survey because it is based on more recent toxicological information. In addition to specifying PELs for airborne exposure, the OSHA lead standard also contains specific provisions dealing with mechanical ventilation, respirator usage, protective clothing, housekeeping, hygiene facilities, employee training, and medical monitoring.[16] The implementation of the provisions of this standard will help to ensure that the employees are protected against any potential adverse health effects of lead exposure.

A copy of the OSHA lead standard was provided to the employer and will not be repeated in this report. However, to assist the employer in implementing the standard's key provisions, a brief overview of these provisions as they relate to the findings of this survey follow.

A. Mechanical Ventilation

The short-term samples identified two key operations which lacked local exhaust ventilation, and as a result, contributed significantly to the airborne lead concentrations. Since the time of the survey, ventilation has been added to these operations.

The existing ventilation for the furnaces, crucible cooling table, and ore preparation areas all appeared to be adequate based on the ventilation measurements taken during the survey. However, some improvements in capture efficiency of these hoods could be gained through the use of flanges and enclosures. Flanges eliminate air flow from irrelevant zones where no contaminants exist, and usually reduce air requirements.[17] In addition, the use of enclosures, particularly on the sides of hoods such as the crucible table, would also reduce the required amount of air for the capture of air contaminants.

Periodic testing of all local exhaust ventilation systems is necessary to ensure their continued efficiency. Such systems should be tested every three months, or following any major modification.[16] A complete discussion of specific details regarding ventilation system testing, as well as information regarding the design, construction, and operation of local exhaust ventilation systems, is contained in the ACGIH Industrial Ventilation, A Manual of Recommended Practice.[17]

B. Air Monitoring

Despite the presence of engineering controls, periodic monitoring for airborne lead is needed to ensure that these controls operate effectively. Air monitoring can also be used to pinpoint the need for further employee protection (i.e., respirators) in certain areas or during certain procedures. When airborne exposures are found to be above the OSHA action level of 30 ug/M^3, as was the case in this survey, the standard calls for repeat monitoring every six months.

This monitoring should be continued until such time as concentrations are found to be below this level in two consecutive measurements conducted at least one week apart.[16] Employees should be informed of the monitoring results.

C. Respiratory Protection

Assuming proper maintenance and fitting, the respirator worn by the employee during the survey should have significantly reduced the employee's actual exposure. Due to their inherent limitations, respirators should not be considered a primary means of employee protection. A more appropriate means of exposure control in this instance would be properly designed engineering controls; i.e., local exhaust ventilation. However, the use of respiratory protection is a suitable means of exposure control in the event that engineering controls can not feasibly reduce the exposure levels. Respirators may also be used as a backup to existing engineering controls when substances of high toxicity are present. In order to ensure the effective use and function of the respirators, a comprehensive respiratory protection plan should be put in place. Such a program is outlined by the American National Standard Institute in the ANSI Standard Z88.6-1984.[18] The program should include a written standard operating procedure which addresses respirator selection, training, fitting, testing, inspection, cleaning, maintenance, storage, and medical examinations. A detailed discussion of these key program elements is provided in the NIOSH <u>Guide to Industrial Respiratory Protection</u>, a copy of which has been provided to the employer.[19]

D. Personal Protective Clothing

Wherever lead dust is present, there is a possibility that the employee's skin and clothing may become contaminated. This can lead to subsequent inhalation or ingestion of the lead, which can substantially increase the employee's overall absorption of lead. In addition, lead contamination on skin or clothing may be transported to other areas of the facility, and possibly to the worker's homes where secondary exposure of co-workers or family members can occur. In one recent study, blood lead levels were found to be markedly higher in household members residing in homes of workers with occupational lead exposure compared to members of homes of people not occupationally exposed to lead.[20] In order to prevent this secondary source of lead exposure, the appropriate use of personal protective equipment is required.

E. Hygiene Facilities and Practices

A separate change room, free from lead contamination, should be provided to the employees to store their "street" clothing. Street clothing should be stored separately from clothing worn during work. If available, showers should be taken at the completion of the work shift to remove any lead that may have reached the employees' skin. Clothing worn at work should not be worn home. Employees should carry necessary personal clothing and shoes home separately, and clean them carefully so as not to contaminate the home.[16]

Food, beverages, or tobacco should not be used or stored in lead contaminated areas. These items can become contaminated with lead and cause subsequent absorption of lead through ingestion or inhalation during eating, drinking, or smoking. Employees should also continue to eat their lunch in a lunchroom separate from the assay lab. All protective clothing should be removed prior to entering the lunchroom, and hands and face should be thoroughly washed.

F. Housekeeping

Housekeeping plays an important role in controlling lead exposures. Dust which has accumulated on surfaces can be reintroduced into the air thereby increasing airborne lead exposures. Also, dust accumulated on chairs or work surfaces can cause unnecessary contamination of the employees protective clothing. Therefore, all surfaces in the assay lab should be kept as free as practicable of the accumulation of lead dust. Vacuuming is the preferred means of removing lead dust. Dry or wet sweeping should not be used except in areas where vacuuming is not feasible. A regular housekeeping program should be established to ensure that all areas are periodically cleaned.

G. Medical Monitoring

While the previously discussed NIOSH recommendations have been aimed at preventing or minimizing lead exposure, NIOSH believes that medical monitoring plays a supplemental role in that it ensures that the other provisions of the program have effectively protected the individual. The OSHA standard for inorganic lead places significant emphasis on the medical surveillance of all workers exposed to levels of inorganic lead above the action level of 30 ug/M^3 TWA. Even with adequate worker education on the adverse health effects of lead and appropriate training in work practices, personal hygiene and other control measures, the physician has a primary responsibility for evaluating potential lead toxicity in the worker. It is only through a careful and detailed medical and work history, physical examinations to rule out other potential causes of symptoms, and appropriate laboratory testing that an accurate assessment can be made. Many of the adverse health effects of lead toxicity are either irreversible or only partially reversible, therefore early detection of disease is very important.[16]

The OSHA lead standard provides detailed guidelines on the frequency of medical monitoring, the important elements in medical histories and physical examinations as they relate to lead, and the appropriate laboratory testing for evaluating lead exposure and toxicity. This standard should be consulted by plant management and the local physician for guidance in carrying out an ongoing medical monitoring program.[16]

In summary, a comprehensive program is necessary for controlling lead exposures during the assay operations. While the company has put into place several key elements of an exposure prevention program, ongoing attention is needed in all of the areas previously discussed in order to effectively reduce the risk of adverse health effects.

It should be noted that the environmental survey covered only those operations related to lead exposure. The sample preparation process, which was not being carried out during the survey, possesses a potential for exposure to crystalline silica. Therefore, an evaluation of exposures during this operation should also be conducted.

IX. REFERENCES

1. Haffty J, Riley LB, Goss WD: A Manual on Fire Assaying and Determination of the Noble Metals in Geological Materials, Geological Survey Bulletin 1445. US Dept of the Interior, Washington DC, 1977.

2. National Institute for Occupational Safety and Health. NIOSH Manual of Analytical Methods. 3rd ed. Cincinnati, Ohio. DHHS (NIOSH) publication no. 84-100, 1984.

3. EPIINFO Software Package Version 2, February 1987. Division of Surveillance and Epidemiologic Studies, EPO, CDC, Atlanta, GA 30333.

4. SPSS/PC for the IBM PC/XT/AT. SPSS Inc. Chicago, IL, 1986.

5. Personal communication, William Babcock, Blood Lead Program Director, USDOL-OSHA Analytical Lab, Salt Lake City, Utah.

6. Blumberg WE, Eisinger J, Lamola AA, Suckerman DM. Priciples and Applications of Hematoflurometry. J.Clinical Lab Automation 1984;4(1): 29-42.

7. Zenz, Carl (ed.), Occupational Medicine: Principles and Practical Applications, 2nd edition, Year Book Medical Publishers, Chicago, 1988.

8. Landrigan I, Popecu HI, Gavanescu O, et al. Reproductive ability of workmen occupationally exposed to lead. Arch Environ Health 1975;30:396-401.

9. Muhaffey K, Annest J, Roberts J, Murphy R: National Estimates of Blood Lead Levels. United States, 1976-1980. NEJM 1982;307:573-9.

10. Annest J, Dirkle J, Makuc C, Nesse J, Bayse D, Kovar M: Chronological Trends in Blood Lead Levels Between 1976 and 1980. NEJM 1983;308:1373-7.

11. Centers for Disease Control. Preventing Lead Poisoning in Young Children: Centers for Disease Control, 1985.

12. Bellinger D, Leviton A, Waternaux C, Needleman H, Rabinowitz M: Longitudinal Analysis of Prenatal and Postnatal Lead Exposure and Early Cognitive Development. NEJM 1987;316:1037-43.

13. Fulton M, Hepburn W, Hunter R, Laxen D, Raab D, Thomson G: Influence of Blood Lead on the Ability of and Attainment of Children in Edinburgh. Lancet 1221-25, 1987.

14. Cullen MR, and Rosenstock L: Clinical Occupational Medicine. W.B. Saunders Company; Philadelphia, PA, 1986.

15. Mine Safety and Health Administration. 30 CFR Chapter 1, Subpart D - Air Quality, Radiation, and Physical Agents. Federal Register, 1985.

16. Occupational Safety and Health Administration. Occupational exposure to lead--final standard (29 CFR Section 1910.1025 - Lead). U.S. Department of Labor, Federal Register 1978 Nov 14:53007.

17. American Conference of Governmental Industrial Hygienists. Industrial Ventilation, A Manual of Recommended Practice, 18th Edition. Lansing, Michigan: ACGIH, 1984.

18. American National Standards Institute, Inc. American National Standard for Respirator Protection - Respirator Use - Physical Qualifications for Personnel. New York: ANSI Inc., 1984.

19. National Institute for Occupational Safety and Health. Guide to Industrial Respiratory Protection. Cincinnati, Ohio. DHHS (NIOSH) publication no. 87-116, 1987.

20. Grandjean P, Bach E: Indirect Exposures: The Significance of Bystanders at Work and at Home. American Industrial Hygiene Journal, Volume 47, 1986.

X. AUTHORSHIP AND ACKNOWLEDGEMENTS

Report Prepared By:	William J. Daniels, CIH, CSP Industrial Hygienist NIOSH - Region VIII Denver, Colorado
	Thomas R. Hales, M.D. Medical Officer NIOSH - Region VIII Denver, Colorado
Originating Office:	Division of Surveillance, Hazard Evaluations & Field Studies Hazard Evaluation and Technical Assistance Branch Cincinnati, Ohio
Environmental Laboratory Analysis:	DataChem Salt Lake City, Utah
Biological Laboratory Analysis:	ESA Laboratories, Incorporated Bedford, Massachusettes

XI. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this Determination Report are currently available upon request from NIOSH, Hazard Evaluations and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Services (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from the NIOSH publications office at the Cincinnati, address. Copies of this report have been sent to:

A. Blue Range Mining Company, Lewistown, Montana
B. Mine Safety and Health Administration - Region VIII
C. Montana State Department of Health
D. NIOSH Regional Offices/Divisions

For the purposes of informing the affected employees, copies of the report should be posted in a prominent place accessible to the employees, for a period of 30 calendar days.

TABLE 1

RESULTS OF ENVIRONMENTAL SAMPLES COLLECTED FOR
AIRBORNE INORGANIC LEAD DURING FIRE ASSAY OPERATIONS
Blue Range Mining Co., Lewistown, Montana
March 13, 1989

SAMPLE TYPE	SAMPLE DESCRIPTION	MINUTES SAMPLED	LITERS SAMPLED	TWA CONCENTRATION LEAD (ug/M3)
Long-Term Samples				
Personal	Assayist - Full-Shift	373	671	850*
Area	Furnace Room On cupel table	352	634	110
Area	Furnace Room Near fusion oven	345	621	74
Area	Furnace Room Near cupel oven	341	614	110
Area	Sample Prep Room In middle of room	339	610	30
Area	Scale Room On weighing table	335	603	30
Area	Break Room On shelf	333	599	< LOD
Short-term Samples				
Personal	Assayist - Short-Term (Preparing Flux Mixture)	38	152	13,000
Personal	Assayist - Short-Term (Dispensing flux without local exhaust ventilation	1.5	6	130,000
Personal	Assayist - Short-Term (Dispensing flux adjacent to local exhaust ventilation)	2.0	8	36,000

Evaluation Criteria - Inorganic Lead
MSHA - 150 ug/M^3, 8-hour TWA
OSHA - 50 ug/M^3, 8-hour TWA

Abbreviations and Key
TWA - Time-weighted average
ug/M^3 - micrograms per cubic meter of air
< LOD - less than the limit of detection of 3.0 micrograms/sample
* - Indicates a calculated 8-hour TWA. All other values are expressed as TWAs for the period of sample collection.

Table 2

List of Symptoms Comprising the Five Symptom Clusters
Blue Range Mining Co., Lewistown, MT

CONSTITUTIONAL	COGNITIVE
Tired	Trouble remembering things
Weak	Difficulty concentrating
Headaches	Make notes to remember things
Dizzy	Confused

GASTROINTESTINAL	EMOTIONAL
Decreased Appetite	Depressed
Diarrhea	Irritable
Nausea	Excitable
Indigestion	Changing Moods

PERIPHERAL NERVOUS SYSTEM
- Decrease in upper extremity strength
- Decrease in lower extremity strength
- Upper extremity paresthesias
- Lower extremity paresthesias

TABLE 3

Lowest Blood Lead Levels Reported To Cause Health Effects In Adults

Blood Lead Level	Health Effect
100-120 ug/dl	Cental Nervous System Toxicity (Encephalopathy)
100 ug/dl	Chronic Renal Damage
80 ug/dl	Low Blood Count (Anemia)
60 ug/dl	Pregnancy Complications
50 ug/dl	Decrease Hemoglobin Production Mild Central Nervous System symptoms
40 ug/dl	Decrease Peripheral Nerve Conduction Pre-term Delivery
30 ug/dl	High Blood Pressure

Table 4

Demographic Characteristics by Assay Lab Employment
Blue Range Mining Co., Lewistown, MT
Blue Range Engineering, Butte, MT

	Assay Lab Employees N=6 # (%)	Non-Assay Lab Employees N=5 # (%)	Significance
Sex (female)	2 (33%)	3 (60%)	p = 0.39*
Race (White)	6 (100%)	5 (100%)	p = Undefined*
Age (mean)	37 yrs	41 yrs	p = 0.68**

* - p-values were calculated using 1-tailed Fisher's exact test.
** - p-values were calculated using a student's t-test for a parametric distribution.

Table 5

Mean Symptom Cluster Scores by Assay Lab Employment[1]
Blue Range Mining Co., Lewistown, MT
Blue Range Engineering, Butte, MT

	Assay Lab Employees N=6	Non-Assay Lab Employees N=5	Significance[2]
Constitutional	5.83	4.60	p = 0.08
Cognitive	6.50	5.40	p = 0.51
GI	4.33	4.60	p = 0.56
Emotional	5.83	4.80	p = 0.13
PNS	5.00	4.00	p = 0.11

1 - Definition of Symptom Cluster Score located in Methods Section.
2 - p-values were calculated using a student's t-test for a parametric distribution.

Table 6

Blood Lead Levels and FEPs by Assay Lab Employment[1]
Blue Range Mining Co., Lewistown, MT
Blue Range Engineering, Butte, MT

	Assay Lab Employees N=6			Non-Assay Lab Employees N=5			Significance[2]
	mean	median	(range)	mean	median	(range)	
Blood Lead (ug/dl)	42	40	(23-65)	18	14	(7-36)	p = 0.02*
FEP (ug/dl)	40	41	(20-68)	19	20	(15-24)	p= 0.05* p= 0.07**

1 - FEPs = Free Erythrocyte Protoporphyrin
2 - Comparing the mean blood lead and FEP among the assay lab employees to the non-assay lab employees
* - p-value calculated using the student's t test for parametric distributions.
**- p-value calculated using the Kruskal-Wallis one-way analysis of variance for non-parametric distributions.